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ABSTRACT

There is increasing pressure to incorporate information technology into schools and increasing interest in evaluating the effects of this technology on students. There has been a growing literature on the assessment of the success of using information technology in schools. This study is timely and potentially valuable because it investigated psychosocial factors in the learning environment where laptop computers are used in the study of mathematics and science. The study combined qualitative and quantitative data collection methods (Tobin & Fraser, 1998) to describe and compare students' perceptions of the actual and preferred learning environments and to explore students' attitudes towards mathematics and science classrooms where laptop computers are used. It has been previously found that positive students' perceptions of their learning environment are linked with their attitude toward and achievement in mathematics and science (Fraser, 1994, 1998). Of particular interest in our study were the differences between male and female students and between subject disciplines of mathematics and science. Because there has been little research reported on the effect of using laptop computers on students' perceptions of their learning environments, this study pioneered the use and validation of a learning environment instrument in laptop schools in Canada. (Contains 37 references.) (Author/MM)

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Investigating the Learning Environment in Canadian Mathematics and Science Classrooms in which Laptop Computers are Used

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Rationale

There is increasing pressure to incorporate information technology into schools and increasing interest in evaluating the effects of this technology on students. This study was timely and potentially valuable because it investigated psychosocial factors in the learning environment where laptop computers are used in the study of mathematics and science.

The study combined qualitative and quantitative data collection methods (Tobin & Fraser, 1998) to describe and compare students' perceptions of their actual and preferred learning environments and to explore students' attitudes towards mathematics and science classrooms where laptop computers are used. It has been previously found that positive learning environments have a favorable effect on students' attitudes towards mathematics and science and on student cognitive achievement in mathematics and science (Fraser, 1994, 1998a). Of particular interest was the difference between male and female students, the differences between actual and preferred learning environments and differences between subject disciplines. Because there has been little research reported on the effect of using laptop computers on students' perceptions of their learning environments, this study pioneered the use of a learning environment instrument in laptop schools in Canada.

Background to the Study

Technology, particularly in the form of computers and online networks, is proliferating in schools world-wide. Computers have been used in education for over 30 years both as an academic discipline and as a tool to assist in teaching and learning. Over the past decade, many schools have

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investigated the educational possibilities of laptop computing. Gardner (1993) found that the impact of using laptops after one year was 'at best marginal' on achievement in mathematics and science, and Fisher and Stolarchuk (1998) reported a more positive relationship between using laptops and student attitudes than between using laptops and academic achievement. Research into the educational use of laptop computers is still in its infancy and further study is needed.

The effects of educational programmes on academic achievement is not necessarily direct. The learning environment could affect students' learning, attitudes and behaviour before it influences their academic achievement. Research into these subtle but critically important psychological and social factors, which make up the learning environment, has developed over the past 30 years beginning with the independent work of Herbert Walberg and Rudolf Moos. Walberg developed the *Learning Environment Inventory* (LEI) to evaluate a new curriculum innovation called the Harvard Project Physics in 1968 (Walberg & Anderson, 1968) and Moos developed several social climate surveys for use in his work in various human environments including psychiatric hospitals. From this work, Moos developed the *Classroom Environment Scale* (CES) (Moos, 1979; Moos & Trickett, 1987). Since then, researchers have continued to conceptualize, assess and investigate the concept of learning environments (Fraser, 1994, 1998a; Wubbels & Levy, 1993). Learning environment instruments have been used to investigate individualized classrooms using the Individualized Classroom Environment Questionnaire (ICEQ), science laboratory classrooms using the Science Laboratory Environment Inventory (SLEI) and constructivist classrooms using the Constructivist Learning Environment Survey (CLES) (Fraser, 1998b).

The use of qualitative methods in learning environment research has provided greater depth and breadth to the understanding and examination of the learning environment (Tobin, Kahle & Fraser, 1990), particularly when qualitative and quantitative methods are combined (Tobin & Fraser, 1998). Much research into classrooms has assessed the learning environment through the perceptions of those participating in the learning on an ongoing basis. This has proven useful as it provides valuable information through the eyes of students or teachers as opposed to an external observer. The use of qualitative data, such as interviews with students and teachers and classroom observations, are useful in helping to contextualize some of the quantitative findings. The use of different-sized samples for different research questions has also been used effectively in studies that combine different research methodologies (Fraser, 1999; Tobin & Fraser, 1998). The development and implementation of useful and valid instruments for assessing classroom environment, together

with the use of narratives (Aldridge, Fraser & Huang, 1999), have provided an excellent framework within which to explore technologically-rich learning environments, including mathematics and science classrooms where all students have laptop computers.

The associations between learning environment variables and student outcomes have provided a particular focus for learning environment research (Fraser, 1998a). This field of research also provides awareness of factors that influence classroom environments. By using the discrepancies between students' perceptions of their actual environment and their preferred environment, teachers can be provided with a basis for growth and change (Yarrow, Millwater & Fraser, 1997). Ultimately, as teaching remains primarily concerned with managing the social interactions in a classroom, the psychosocial environment appears critical when evaluating the use of new technologies like school-wide laptop computing programmes in teaching and learning.

Aims

To modify and validate instruments for use in Canadian high school mathematics and science classrooms using laptop computers to measure:

a) students' perceptions of actual and preferred classroom learning environment

b) students' attitudes towards their science and mathematics classes and towards the use of laptop computers

To describe and compare students' perceptions of the actual and preferred learning environments of their mathematics and science classes.

To determine whether perceptions of the actual and preferred learning environments differ:

a) for male and female students

b) for science and mathematics classes

To determine whether associations exist between perceptions of the learning environment and students' attitudes towards their mathematics and science classes and towards using laptop computers.

Research Methods

This study initially involved the administration of a large-scale quantitative questionnaire which involved surveying 1,173 students in 73 mathematics and science classrooms in four difference co-educational independent boarding and day schools in Ontario, Canada. After the initial data analysis, classrooms were selected for case studies. The incorporation of qualitative data, collected by classroom observations and student and teacher interviews, was invaluable in providing greater insight into the quantitative data and adding depth and breadth to the data analysis. These qualitative data have been useful in helping to explain some of the quantitative findings. This study was multilevel in that it has combined multiple data sources and grain sizes (Fraser, 1999). The advantage of combining qualitative and quantitative methods include greater credibility of findings due to the triangulation of data.

The learning environment instrument that was chosen for this study was the WIHIC (What is Happening in this Class?) questionnaire. This instrument, designed, field tested and validated by Fraser, McRobbie and Fisher (1996), brings together into a single instrument the best features of a range of past learning environment questionnaires and combines these with contemporary emphases. This instrument has been used and validated in a variety of countries and in a variety of classroom settings. In Taiwan, Aldridge and Fraser (2000) conducted a cross-national study exploring the cultural differences between science classrooms in Taiwan and Australia. The WIHIC also has been used successfully in Singapore (Fraser & Chionh, 2000), Canada (Zandvliet & Fraser, 1998), the United States (Moss & Fraser, 2001) and Indonesia (Margianti, Fraser & Aldridge, 2001).

While several other existing learning environment instruments contain scales which would be pertinent, several scales would not be of interest. The WIHIC's seven scales contain items which appear most appropriate in contemporary classroom setting in which laptop computers are used.

The 'personal' rather than the 'class' form of the instrument was used for this study (McRobbie, Fisher & Wong, 1998). The personal form of the questionnaire asks students for their perceptions of their own role in the class, rather than their perceptions for the whole class. The personal form is more suited for investigations of the classroom environment perceptions of within-class groupings, such as gender groups, or for the construction of case studies of individuals. The 'actual' and 'preferred' forms were also used in this study. Both forms are important when investigating whether

sub-groups within the class perceive the environment similarly, as well as for describing their ideal or preferred environment so as to provide teachers with feedback on students' perceptions of their learning environment.

The original WIHIC contained 56 items in seven scales which assess students' perceptions of classroom learning environment:

Student Cohesiveness:	The extent to which students know, help and are supportive of one another
Teacher Support:	The extent to which the teachers helps, befriends, trusts, and is interested in students
Involvement:	The extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class
Investigation:	The emphasis on the skills and processes of inquiry and their use in problem solving and investigation
Task Orientation:	The extent to which it is important to complete activities planned and to stay on the subject matter
Cooperation:	The extent to which students cooperate rather than compete with one another on learning tasks
Equity:	The extent to which students are treated equally by the teacher

Each item has the five response alternatives of Almost Never, Seldom, Sometimes, Often and Very Often.

As part of this questionnaire, an additional classroom environment scale was added to assess the students' perceptions of the amount and type of the computer usage in each class. In addition, students completed questions pertaining to their attitudes towards the subject (mathematics/science), based on the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981), and towards computer use, based on the Computer Attitudes Survey (CAS) (Loyd & Gressard, 1984). These two attitude scales were included to permit investigation of predictors of classroom environment (namely, gender and subject) and of associations between learning environment and student attitudes.

Data Analysis and Findings

Data collected from the sample of 1,173 students was used to investigate the modified WIHIC survey's reliability and validity using the following criteria: factor structure, internal consistency reliability, discriminant validity and the ability to distinguish between different classes and groups. These statistical measures are reported in the first section below to provide evidence of the

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usefulness of this instrument in describing the psychosocial factors influencing the learning environment in mathematics and science classrooms in laptop computer programme schools in Canada. To address Research Questions 2 and 3, effect sizes and *t*-tests were used in exploring the magnitude and statistical significance of the differences between actual and preferred scores, between boys' and girls' scores, and between mathematics and science classrooms where laptop computers are used. These findings are reported in the second and third sections below. To address Research Question 4, simple correlation and multiple regression analyses were conducted to investigate associations between students' attitudes and their classroom environment perceptions. Finally, the fifth section describes the case studies that were conducted in selected classrooms at one of the schools.

Questionnaire Reliability and Validity

The first research question is as follows:

> Is it possible to modify and validate instruments for use in Canadian high school mathematics and science classrooms using notebook computers to measure:
>
> a) students' perceptions of the classroom learning environment?
> b) students' attitudes towards their science and mathematics classes?
> c) students' attitudes towards the use of notebook computers?

Prior to further analyses, the questionnaire was refined to maximize validity and reliability. Each scale's factor structure, internal consistency reliability, discriminant validity and ability to distinguish among different class groupings were investigated. Together, these statistics gave an indication of the suitability of this questionnaire for describing the psychosocial environment in the classrooms studied, as well as providing support for the validity of the questionnaire for its future use in laptop computer classrooms.

Factor Analysis of the WIHIC. Factor analysis is a data-reduction technique used to reduce a large number of items to a smaller set of underlying factors (Coakers & Steed, 1996). Using the WIHIC questionnaire data obtained from 1,173 students, factor and item analyses were conducted in order to identify faulty items that could be removed in order to improve the internal consistency reliability and factorial validity of the eight scales in the modified WIHIC. Several principal component factor

analyses with varimax rotation eventually resulted in the factor loadings found in Table 1. Varimax rotation, in which the factor axes are kept at right angles to each other, is frequently used in the validation of learning environment instruments. Ordinarily, rotation reduces the number of complex variables and enhances interpretation (Coakers & Steed, 1996). Table 1 presents results separately for the actual and preferred versions of the WIHIC.

As a result of the factor analyses, 10 items that did not fit the factor structure were removed from the original questionnaire in the following scales: Student Cohesiveness (Items number 3, 5, 6), Involvement (Item number 23), Investigation (Item number 28), Task Orientation (Item number 38, 40), and Equity (Items number 49, 54). This improved the internal consistency reliability and factor structure. In Table 1, all factor loadings smaller than 0.4 have been omitted.

The *a priori* eight-factor structure of the actual version of the refined version of the questionnaire was replicated using the individual as the unit of analysis with nearly all of the items having a factor loading of at least 0.4 on its own scale and on no other scales (see Table 1). The only two exceptions for the actual form occurred for Items 21 and 24 in the Involvement scale, whose loadings with their own scale were less than 0.4. For the preferred form of the WIHIC, all items except Item 13 had a loading of at least 0.4 with their *a priori* scale. For both the actual and preferred forms, Table 1 shows the factor loading with all other scales (besides the *a priori* scale) are all less than 0.4.

The bottom of Table 1 shows that the total amount of variance accounted for by the 52 items in eight scales is 54.09% for the actual form and 50.64% for the preferred form. Table 1 also shows that eigenvalues range from 1.36 to 11.41 for the actual form and from 2.00 to 4.02 for the preferred form. Overall, the data in Table 1 provide strong support for the factorial validity of the eight-scale version of the WIHIC in both its actual and preferred forms.

Internal Consistency and Discriminant Validity of the WIHIC. Internal consistency reliability is a measure of whether each item in a scale measures the same construct. The internal consistency for each scale was established using Cronbach's alpha coefficient for two units of analysis (the individual and class mean). Table 2 shows that the alpha coefficients of different WIHIC scales were high, ranging from 0.76 to 0.92 using the individual as the unit of analysis and from 0.78 to 0.95 for class means.

Table 1. Factor Loadings for the Actual and Preferred Version of the WIHIC

Item Number	Student Cohesiveness		Teacher Support		Involvement		Investigation		Task Orientation		Cooperation		Equity		Computer Usage	
	Actual	Pref	Actual	Pref	Actual	Pref	Actual	Pref	Actual	Pref	Actual	Pref	Actual	Pref	Actual	Pref
1	.67	.63														
2	.43	.61														
4	.76	.50														
7	.50	.63														
9			.51	.66												
10			.70	.69												
11			.67	.65												
12			.59	.46												
13			.68	--												
14			.49	.64												
15			.62	.61												
16			.50	.46												
17					.76	.66										
18					.79	.69										
19					.41	.56										
20					.59	.60										
21					--	.42										
22					.41	.49										
24					--	.42										
25							.65	.67								
26							.46	.54								
27							.71	.69								
29							.63	.65								
30							.71	.73								
31							.54	.72								
32							.60	.58								
33									.63	.64						
34									.53	.67						
35									.60	.67						
36									.51	.64						
37									.67	.63						
39									.55	.69						
41											.61	.49				
42											.51	.53				
43											.61	.51				
44											.40	.75				
45											.64	.63				
46											.51	.61				
47											.66	.56				
48											.56	.54				
50													.54	.46		
51													.64	.60		
52													.72	.68		
53													.69	.73		
55													.68	.65		
56													.69	.65		
57															.78	.78
58															.70	.75
59															.61	.69
60															.77	.79
61															.68	.82
62															.63	.76
%Variance	2.62	3.80	21.95	7.21	3.06	5.47	7.43	7.73	3.40	6.68	6.04	6.70	5.37	5.91	4.22	7.14
Eigenvalue	1.36	2.00	11.41	3.75	1.60	2.85	3.87	4.02	1.77	3.48	3.14	3.49	2.80	3.07	2.20	3.71

Factor loadings smaller than 0.40 have been omitted.
N= 1,173 students in 73 classes in Canada.

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Discriminant validity (using the mean correlation of one scale with other scales in the WIHIC as a convenient index) assesses the extent to which a scale is unique in the dimension that it covers and is not included in another scale in the same instrument. The discriminant validity of the actual form of the WIHIC ranged from 0.10 to 0.38 for the individual as the unit of analysis and from 0.18 to 0.45 the class means (see Table 1). These results suggest that each scale assesses a unique dimension and that, while there is some overlap between raw scores on scales, they are relatively independent of each other. Moreover, the factor analysis results attest to the independence of factor scores.

Ability of the WIHIC Scales to Differentiate between Classes (ANOVA)

Another desirable characteristic of the actual form of any classroom environment scale is that it is capable of differentiating between the perceptions of students in different classrooms. That is, students within the same class should see its environment relatively similarly, whereas average class perceptions should vary from class to class.

A one-way analysis of variance (ANOVA) was performed for the scores on each WIHIC scale to investigate its ability to differentiate between the perceptions of students in different classrooms. Table 2 reports the results in terms of eta^2, which is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance in scale scores which is attributable to membership in that class.

The value of eta^2 ranged from 0.01 to 0.11 for different scales and was statistically significant ($p<0.05$) for all scales except Cooperation (Table 2). This suggests that nearly all scales of the WIHIC are able to differentiate between the perceptions of students in different classes.

Validity and Reliability of the Attitude Questionnaire. Students' attitude towards science and mathematics were assessed using six items based on Fraser's (1981) *Test of Science Related attitudes* (TOSRA). The six items measure the extent to which students enjoy, are interested in and look forward to science lessons. An example of an attitude item is "I really enjoy going to science class". The wording was changed for mathematics classes to read "I really enjoy going to mathematics class". All items selected are scored positively.

Table 2. Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for Two Units of Analysis and Ability to Differentiate between Classrooms (ANOVA Results) for the WIHIC

Scale	Unit of Analysis	Number of Items	Alpha Reliability		Mean Correlation with other Scales		ANOVA eta^2
			Actual	Preferred	Actual	Preferred	Actual
Student Cohesiveness	Individual	4	0.76	0.65	0.27	0.29	0.02**
	Class Mean		0.78	0.68	0.31	0.39	
Teacher Support	Individual	8	0.85	0.80	0.33	0.37	0.05**
	Class Mean		0.93	0.85	0.33	0.41	
Involvement	Individual	7	0.84	0.87	0.38	0.49	0.03**
	Class Mean		0.83	0.90	0.45	0.50	
Investigation	Individual	7	0.85	0.90	0.34	0.45	0.02**
	Class Mean		0.90	0.95	0.44	0.49	
Task Orientation	Individual	6	0.79	0.87	0.29	0.35	0.02**
	Class Mean		0.87	0.89	0.32	0.40	
Cooperation	Individual	8	0.77	0.85	0.28	0.38	0.01
	Class Mean		0.79	0.87	0.38	0.51	
Equity	Individual	6	0.88	0.84	0.31	0.34	0.02*
	Class Mean		0.90	0.88	0.39	0.41	
Computer Usage	Individual	6	0.85	0.90	0.10	0.16	0.11**
	Class Mean		0.94	0.95	0.18	0.23	

* $p<0.05$
** $p<0.01$
N= 1,173 students in 73 classes in Canada.
The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

The students' attitudes towards using computers were assessed using eight items based on Loyd and Gressard's (1984) *Computer Attitudes Survey* (CAS). The items selected measure the extent to which students enjoy, are interested in, and look forward to working with computers. An example of an item is "I like to use my computer a lot in class". All items selected are scored positively.

Factor analysis was also conducted for the attitudinal scales for the sample of 1,173 students. Two items were removed because of their factor loadings in order to improve the factor structure. With these items removed, the *a priori* two-scale structure was perfectly replicated. Each of the remaining 12 items had a factor loading of at least 0.4 on its own scale and less than 0.4 on the other scales. The factor loadings can be found in Table 3. Together, the two scales accounted for 61.27% of the variance.

Table 3. Factor Loadings for the Attitude Items

Item Number	Factor Loading	
	Attitudes towards Subject	Attitudes towards Computers
SA64	0.84	
SA65	0.84	
SA66	0.86	
SA67	0.88	
SA68	0.80	
SA69	0.82	
CA70		0.57
CA71		0.47
CA72		0.85
CA73		0.80
CA75		0.83
CA77		0.70
%Variance	35.33	25.94
Eigenvalue	4.24	3.11

Factor loadings smaller than 0.40 have been omitted.
N=1,173 students in 73 classes in Canada

Table 4 provides information about the internal consistency reliability and discriminant validity of the two attitude scales. Table 4 shows that both attitude scales exhibited high reliability with an alpha coefficient of 0.92 for individuals and 0.95 for class means for Attitudes towards Subject and of 0.79 for individuals and 0.78 for class mean for Attitudes towards Computers. The index of discriminant validity used in Table 4 is the correlation between scales. The correlation between Attitudes towards Subject and Attitudes towards Computers was 0.22 for individuals and 0.67 for class means. Again, as was seen with the WIHIC, these scores suggest that the two attitude scales show reasonable independence.

In answer to the first research question, it appears that both the WIHIC and the attitudinal scales used in this study are reliable and valid when used with grade 7-12 mathematics and science classrooms in Canada where laptop computers are used.

Table 4. Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Scale Intercorrelation) for Attitude Scales

Scale	Unit of Analysis	Number of Items	Alpha Reliability	Scale Intercorrelation	
				Attitude to Science	Attitude to Computers
Attitudes towards Subject	Individual	6	0.92	-	0.22
	Class Mean		0.95	-	0.67
Attitudes towards Computers	Individual	6	0.79	0.22	-
	Class Mean		0.78	0.67	-

N=1,171 students in 73 classes in Canada

Describing and Comparing Actual and Preferred Learning Environment

The study's second research question is listed below:

> Is it possible to describe and compare students' perceptions of the actual and preferred learning environments of their mathematics and science classes?

Descriptive statistics (means and standard deviations) were used to characterize the average classroom environment for mathematics and science classes. Two separate units of analysis were used: the individual (reflecting the distinct view of the classroom held by an individual) and the class mean (reflecting the collective view of members of the same class). These two units of analysis reflect the difference between the 'private beta press' and the 'consensual beta press' (Pace & Stern, 1958).

Actual and preferred environments are compared in Table 5. Because the number of items in the refined version of the scales differed, the average item mean (i.e. the scale mean divided by the number of items in the scale) was used as a basis of comparison between scales. The standard deviation of each WIHIC scale is provided in Table 5 as a measure of the extent to which the scores deviate from their mean for each scale. The means generated from each class were used as the primary source for comparison of students' perceptions.

A one-way MANOVA for repeated measures was conducted for each WIHIC scale, using the class means as the unit of analysis, to determine whether there were statistically significant differences between actual scores and preferred scores. Because the multivariate test was statistically significant using Wilks' lambda criterion, a *t*-test for paired samples was calculated and interpreted for each individual scale (see Table 5) to ascertain differences between actual and preferred scores.

Table 5 shows that differences between actual and preferred environment are statistically significant ($p<0.01$) for all WIHIC scales for both units of analysis. For all scales, students preferred a more favourable classroom environment than the one that they perceived to be actually present. This pattern is consistent with considerable past research (Fisher & Fraser, 1983).

Table 5. Average Item Mean, Average Item Standard Deviation and Difference between Actual and Preferred Scores (Effect Size and *t* Test for Paired Samples) for the WIHIC for Two Units of Analysis

Scale	Unit of Analysis	Average Item Mean		Average Item Standard Deviation		Difference	
		Actual	Preferred	Actual	Preferred	Effect Size	*t*
Student Cohesiveness	Individual	4.25	4.65	0.61	0.57	0.68	23.63**
	Class mean	4.25	4.65	0.20	0.21	1.95	16.17**
Teacher Support	Individual	3.77	4.38	0.80	0.62	0.86	28.44**
	Class mean	3.76	4.37	0.34	0.20	2.26	19.41**
Involvement	Individual	3.54	4.10	0.72	0.68	0.80	29.42**
	Class mean	3.54	4.10	0.24	0.22	1.96	23.13**
Investigation	Individual	3.49	4.05	0.80	0.76	0.72	27.23**
	Class mean	3.50	4.04	0.28	0.26	1.38	23.81**
Task Orientation	Individual	4.21	4.73	0.63	0.46	0.95	32.67**
	Class mean	4.21	4.73	0.24	0.14	2.74	24.16**
Cooperation	Individual	4.04	4.40	0.70	0.62	0.55	22.47**
	Class mean	4.03	4.39	0.23	0.21	1.64	21.77**
Equity	Individual	4.18	4.67	0.78	0.47	0.77	24.14**
	Class mean	4.17	4.67	0.25	0.14	2.50	20.28**
Computer Usage	Individual	3.25	3.60	1.13	1.10	0.32	14.59**
	Class mean	3.23	3.56	0.73	0.58	0.53	9.59**

**$p<0.01$ N=1,173 students in 73 classes

Also effect sizes were calculated to estimate the magnitude of the differences between the actual and preferred scores as recommended by Thompson (1998). Effect sizes represent the differences between actual and preferred means expressed in standard deviation units. Table 5 shows that effect sizes, using the individual as the unit of analysis, range from approximately one third of a standard deviation for Computer Usage (0.32) to almost one standard deviation unit for Task Orientation (0.95). Using the class mean as the unit of analysis, the ranges are even greater, ranging from half of a standard deviation for Computer Usage to over two standard deviations for Teacher Support, Task Orientation and Equity The magnitude of these effect sizes suggest that the actual-preferred differences are educationally important as well as being statistically significant.

Figure 1 is a graph of students' average perceptions of their actual and preferred classroom environments. The profiles clearly reflect that students in the sample, on average, prefer more of every dimension assessed by the WIHIC.

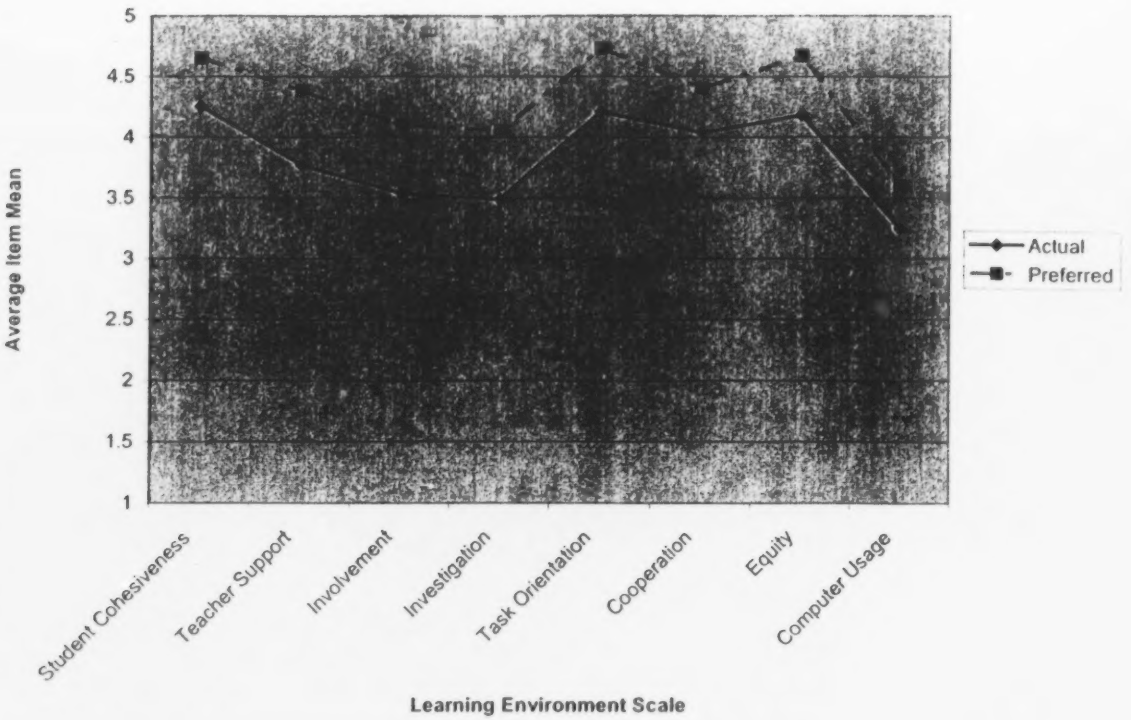

Figure 1. Average Item Means for the Actual vs. Preferred versions of the WIHIC

Comparing the Learning Environment and Attitude Scores of Male and Female Students and of Mathematics and Science Students

The third research question is:

> Do perceptions of the actual and preferred learning environments differ for:
>
> a) male and female students?
>
> b) mathematics and science classes?

It is well documented (Parker, Rennie & Fraser, 1996; Sadker & Sadker,1994) that women are under-represented in mathematics and science courses and careers and that boys outperform girls in science (especially physical science). As well, research (Durndell & Thomson, 1996; Sutton, 1991) describes the differing ways in which girls and boys use information technology and their different attitudes towards computers. There are several possible explanations for these differences including the psychosocial factors influencing the classroom learning environment such as those assessed by the various scales of the WIHIC.

Because boys and girls are not found in equal numbers in every class, the unit of analysis chosen was the within-class gender mean. That is, a boys' mean and a girls' mean were generated for each of the 73 classes for each scale (because all the four schools examined were coeducational institutions). The use of this unit of analysis avoids the confounding that can arise if the individual were to be used as the unit of analysis.

The other determinant of environment and attitude scores in our study was the subject (mathematics or science). Data were analyzed to shed light on whether mathematics students hold different classroom environment perceptions and attitudes relative to science students.

The differences in boys' and girls' scores and between mathematics and science classes, as measured by the WIHIC and attitude scores, were analyzed using a two-way MANOVA with repeated measures on one factor (namely, gender). Because the multivariate test produced significant results using Wilks' lambda criterion, the univariate two-way ANOVA was interpreted for each WIHIC actual scale, each WIHIC preferred scale and each attitude scale to determine if boys and girls had different scores. Table 6 shows for each scale the average item mean for each of the four groups (male mathematics students, male science students, female mathematics students and female science students), the average item standard deviation for each group, and the ANOVA results for gender and subject differences.

Table 6 shows that differences between males' and females' scores are statistically significant for two actual learning environment scales, three preferred learning environment scales and the two attitude scales ($p<0.05$). For the two attitude scales and preferred Computer Usage, males' scores were significantly greater than females' scores. On the other hand, there are five cases for which females' scores are significantly greater than males' scores, namely, preferred Teacher Support, both actual and preferred Cooperation, and both actual and preferred Equity. This pattern in which females' actual and preferred learning environment scores generally are higher than males' scores replicates past research (Henderson, Fisher & Fraser, 1995; Wong & Fraser, 1996). Also the finding that males have a higher preference for Computer Usage than females is supported generally in past research (Kelly, 2000).

The effect sizes for gender differences also are shown in Table 6 in terms of the differences between male and female means expressed in standard deviation units. The effect sizes for the statistically

significant differences in Table 6 range from approximately a third of a standard deviation to 0.84 standard deviations. This suggests educationally important differences between males and females.

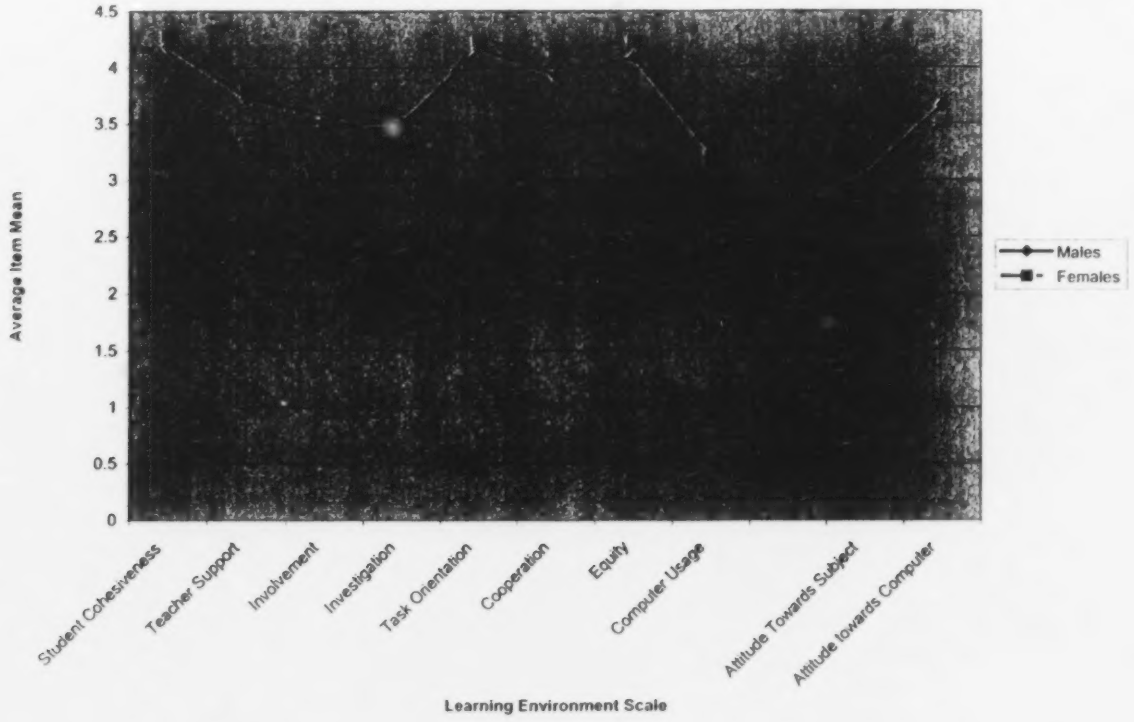

Figure 2. Differences between Males' and Females' Scores for Actual WIHIC and Attitude Scales

Figure 2 provides a graphical representation of the average item mean for each WIHIC actual scale and each attitude scale. This graph illustrates that, although girls tend to have more favourable perceptions on most classroom environment scales, boys have more positive attitudes scores for Attitude towards the Subject and Attitude towards Computer than girls.

Table 6. Two-Way ANOVA Results for Gender and Subject Differences in Learning Environment and Attitudes Using the Within-Class Gender Subgroup Mean as the Unit of Analysis

Scale	Form	Average Item Mean				Average Item Standard Deviation				ANOVA Results				
										Gender		Subject		Gender x Subject
		Male Math	Male Science	Female Math	Female Science	Male Math	Male Science	Female Math	Female Science	Effect Size	F	Effect Size	*F*	*F*
Student Cohesiveness	Actual	4.19	4.23	4.37	4.21	0.34	0.27	0.31	0.34	-0.25	2.59	0.19	1.07	3.86
	Preferred	4.53	4.68	4.72	4.64	0.46	0.34	0.27	0.25	-0.23	1.83	-0.11	0.47	5.80*
Teacher Support	Actual	3.63	3.78	3.88	3.72	0.61	0.38	0.47	0.50	-0.19	1.61	0.01	0.00	4.93*
	Preferred	4.33	4.32	4.46	4.42	0.33	0.28	0.25	0.18	-0.44	8.94**	0.10	0.34	0.10
Involvement	Actual	3.54	3.58	3.54	3.47	0.45	0.38	0.46	0.37	0.13	0.79	0.04	0.04	0.63
	Preferred	4.01	4.08	4.14	4.13	0.42	0.36	0.38	0.24	-0.26	1.41	-0.09	0.00	0.00
Investigation	Actual	3.39	3.56	3.39	3.52	0.45	0.32	0.48	0.39	0.05	0.10	-0.37	4.54*	0.08
	Preferred	3.95	4.01	4.00	4.18	0.49	0.34	0.48	0.29	-0.28	0.66	-0.30	7.21**	0.48
Task Orientation	Actual	4.12	4.13	4.21	4.23	0.52	0.31	0.46	0.38	-0.23	2.06	-0.04	0.03	0.21
	Preferred	4.74	4.79	4.74	4.74	0.53	0.37	0.42	0.44	0.06	0.71	-0.06	0.99	0.84
Cooperation	Actual	3.90	3.94	4.15	4.11	0.32	0.38	0.53	0.34	-0.54	10.64**	0.00	0.00	0.28
	Preferred	4.34	4.33	4.41	4.50	0.30	0.39	0.38	0.28	-0.36	5.79**	-0.12	0.49	0.62
Equity	Actual	4.00	4.16	4.26	4.18	0.56	0.39	0.37	0.43	-0.32	4.74*	-0.09	0.79	5.80*
	Preferred	4.62	4.60	4.75	4.69	0.25	0.34	0.16	0.19	-0.47	7.37**	0.17	2.67	0.20
Computer Usage	Actual	2.86	3.61	2.80	3.52	0.73	0.69	0.74	0.80	0.10	0.77	-0.99	25.80**	0.37
	Preferred	3.41	3.89	3.18	3.78	0.61	0.63	0.69	0.57	0.27	3.39	-0.86	19.58**	0.67
Attitude to Science/Mathematics		2.82	3.23	2.71	3.03	0.49	0.42	0.44	0.48	0.34	5.52*	-0.80	14.75**	0.54
Attitude to Computers		3.54	3.71	3.25	3.30	0.55	0.34	0.43	0.34	0.84	27.83**	-0.27	2.49	1.36

Sample size is 38 within-class gender subgroup means for mathematics and the same for science.
*$p<0.05$ **$p<0.01$

Table 6. Two-Way ANOVA Results for Gender and Subject Differences in Learning Environment and Attitudes

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Table 6 also reports the differences between science and mathematics classes on each scale in terms of both effect sizes and the ANOVA. Table 6 shows that differences between science and mathematics classes are statistically significant for both actual and preferred Investigation, both actual and preferred Computer Usage, and Attitudes towards Subject (mathematics and science). For these five significant differences, the effect size ranges from approximately one-third standard deviations to one standard deviation. For each significant difference, scores are higher for science classes than for mathematics classes. A graph depicting differences between mathematics and science classes is provided in Figure 3 for actual environment and attitude scales.

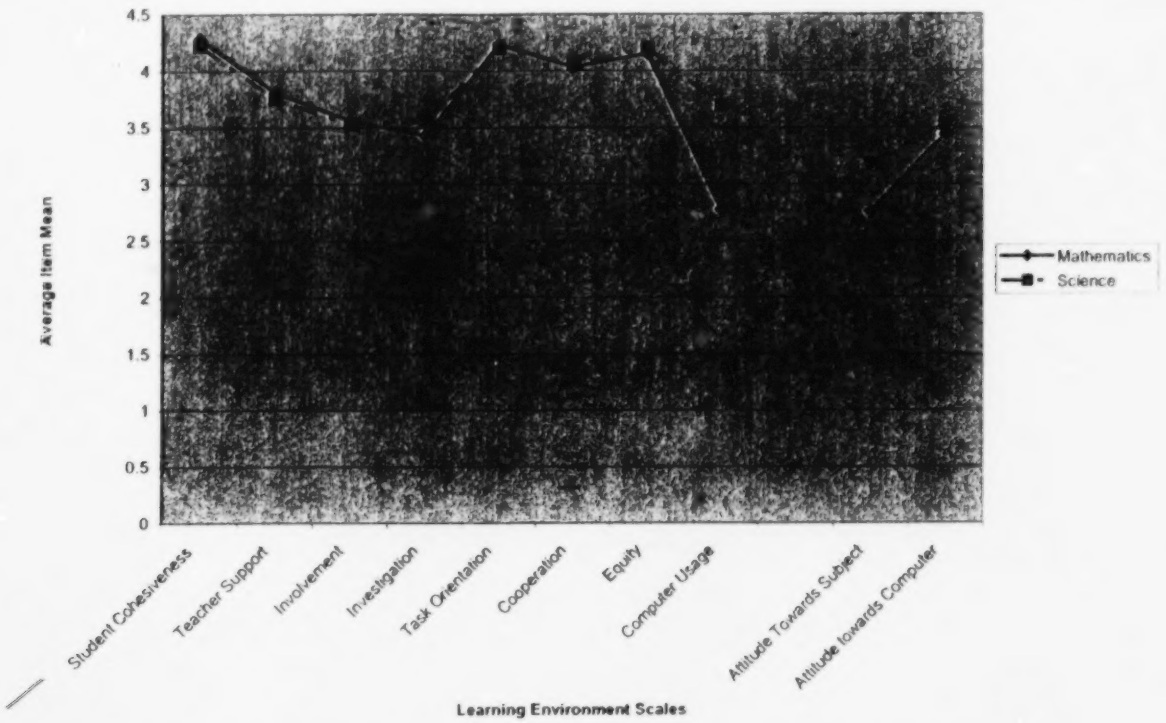

Figure 3. Differences between Science and Mathematics Classes for Actual WIHIC and Attitude Scales

Associations between Learning Environment and Attitude Scales

The fourth research question is as follows:

> Do associations exist between perceptions of the learning environment and students' attitudes towards:
>
> a) their mathematics and science class?
>
> b) computers and computer use?

Learning environment research often has involved investigating associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial aspects of their learning environment (Fraser, 1998a; Fraser & Chionh, 2000; Fraser & McRobbie, 1993).

Table 7. Simple Correlation and Multiple Regression Analyses for Associations Between Student Attitudes and Dimensions of the WIHIC

Scale	Unit of analysis	Attitude-Environment Association			
		Student Attitude Towards Subject		Student Attitude Towards Computers	
		r	*β*	*r*	*β*
Student Cohesiveness	Individual	0.06*	0.09**	0.10**	0.04
	Class Mean	0.13	0.03	0.36**	0.30*
Teacher Support	Individual	0.36**	0.14**	0.05	0.04
	Class Mean	0.30*	0.11	-0.08	-0.17
Involvement	Individual	0.31**	0.13**	0.15**	0.13**
	Class Mean	0.23	-0.02	0.19	-0.05
Investigation	Individual	0.32**	0.12**	0.13**	0.02
	Class Mean	0.35**	0.08	0.20	0.06
Task Orientation	Individual	0.29**	0.14**	0.10**	0.06
	Class Mean	0.20	0.03	0.15	0.09
Cooperation	Individual	0.06*	-0.11**	0.06*	-0.03
	Class Mean	0.12	-0.14	0.24*	0.02
Equity	Individual	0.31**	0.14**	-0.05	-0.16**
	Class Mean	0.46**	0.29*	0.08	0.00
Computer Usage	Individual	0.16**	0.13**	0.25**	0.23**
	Class Mean	0.43**	0.34**	0.40**	-0.05
Multiple Correlation (*R*)	Individual		0.47**		0.32**
	Class Mean		0.59**		0.52**

* $p<0.05$
** $p<0.01$ N= 1,171 students in 73 classes

Associations were explored between student's Attitude towards Subject and Attitude towards Computers and each of the WIHIC scales for two units of analysis. These relationships were

explored using simple correlations and multiple regression analyses. Attitude-environment associations are reported in Table 7.

Simple correlations indicate the bivariate association between each attitude scale and each of the learning environment scales. The multiple regression analysis provides a test of the combined influence of the set of learning environment scales on each attitude scale. The regression coefficients in Table 7 indicate whether a particular learning environment scale is related to attitudes when all of the other WIHIC scales are mutually controlled.

With the individual as the unit of analysis, Table 7 shows that the simple correlation with attitudes was statistically significant ($p<0.05$) for all WIHIC scales for Attitude towards Subject and for five WIHIC scales (namely, Student Cohesiveness, Involvement, Investigation, Task Orientation, Cooperation and Computer Usage) for Attitude towards Computers. With the class as the unit of analysis, there were four statistically significant simple correlations between Attitude towards Subject and WIHIC scales (namely, Teacher Support, Investigation, Equity and Computer Usage) and three significant simple correlations between Attitude towards Computers and a WIHIC scale (namely, Student Cohesiveness, Cooperation and Computer Usage). It is noteworthy that all simple correlations in Table 7 are positive, thus confirming the link between a favourable classroom environment and student attitudes.

The bottom of Table 7 shows that the multiple correlation between an attitude scale and the set of eight WIHIC scales was statistically significant for each attitude scale at both levels of analysis. In order to ascertain which specific learning environment scales account for most of the variance in attitudes scales, standardized regression weights were examined.

Table 7 shows that, for Attitude to Subject, all WIHIC scales were significant independent predictors of attitudes at the student level, whereas only Equity and Computer Usage were significant independent predictors of attitudes at the class level. For Attitude towards Computers, three WIHIC scales (Involvement, Equity and Computer Usage) are significant independent predictors at the student level of analysis, whereas Student Cohesiveness is the only WIHIC scale that is a significant independent predictor at the class level.

Overall, the pattern attitude-environment associations found in Table 7 replicates considerable prior research (Fraser, 1994, 1998).

Case Study

The fifth research question is:

> Is it possible to use case studies to help to describe classroom environments in which notebook computers are used, to identify factors which influence the classroom environment, and to explain how differences in classroom environments lead to differences in students' attitudes?

Based on the findings obtained when quantitative data were analyzed separately for each class, we provided participating teachers with feedback about their own classes. Several of these classes were selected to form case studies. An example of one such case was Mrs Ross' grade 8 science class. Mrs Ross is a young female teacher in her third year of teaching. The course was web-based, with all materials, course notes, assignments, rubrics, some virtual labs and CD ROMs available to the students both in and out of class time. The students in this grade were in their second year of the laptop programme.

As evident in Figure 4, students' perceive their actual environment as being very close to what they would prefer as their ideal classroom environment. Given this favourable data from Mrs Ross' three classes, we employed interpretative procedures recommended by Erickson (1998) to help inform the qualitative findings. Classroom observations were made by one of the authors as a participant observer, and field notes were recorded over 10 hour-long lessons. Students were then interviewed individually or in small groups in order to seek clarification about specific areas of the questionnaire. Student responses to various questions pertaining to learning environment scales of the WIHIC are described below.

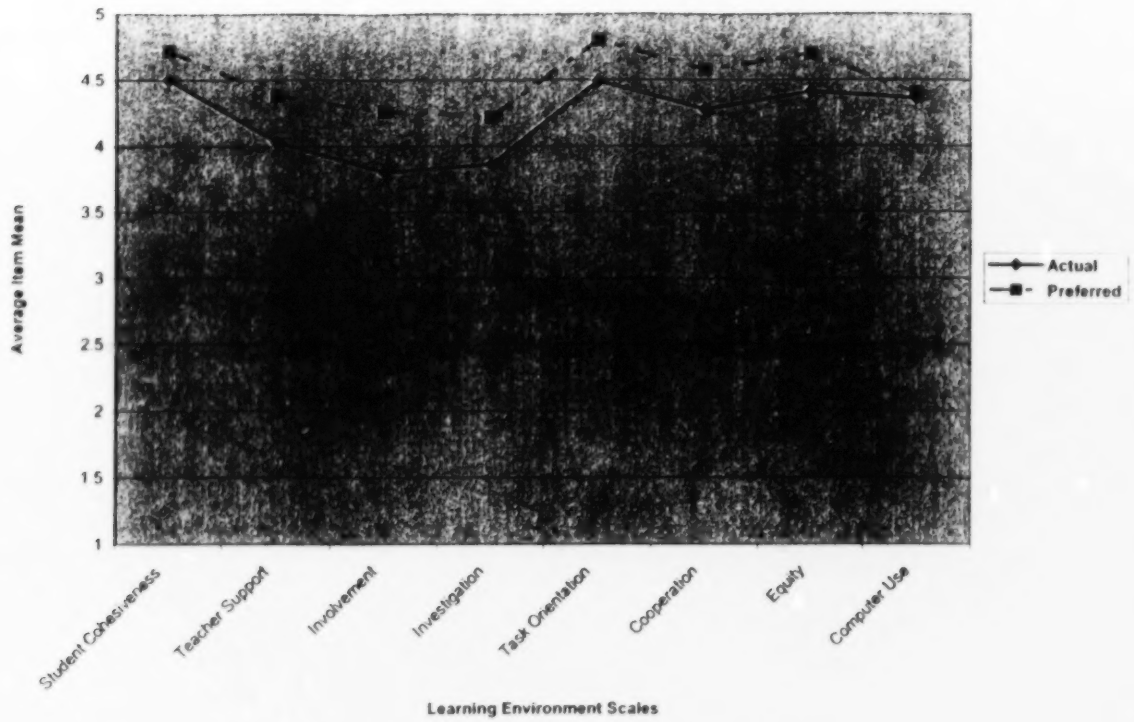

Figure 4. Actual and Preferred Learning Environment Scores for Mrs Ross' Class

While students in these three classes have a high actual Student Cohesiveness score of 4.5, we were interested to know why their preferred environment scores were even higher. Clearly, these students are pleased with the extent to which they are able to know, help and support one another:

> I like the fact that our desks are arranged like they are. The pods allow us to work together easily.
> Yeah, we are allowed to talk and share answers in this class.
> I sometimes find that I just work by myself because it is easy and I am ahead of my friends.
> We talk about sports and stuff, but we still get our work done.
> We know all the kids in our class well, we see them for most classes each day.

The students' actual Computer Usage scores are close to their ideal scores (Figure 4). Students reported things such as:

> The CD and ROM and multimedia take lots of time and some are childish-too easy.
> I like the CD and the resources but when we just read on the screen-I'd rather have paper.
> When it does funny things, I don't like it.

The honeymoon is over with computers and I am less tempted to fool around now with instant messenger and AOL.

I love the computer-you can go online to get info instead of notes.

The chat-line was cool.

Hard to fool around without getting caught.

The virtual labs help you picture the concept.

The teacher spent most of the class time circulating amongst the students to ensure that they were engaged, to clarify concepts and to encourage students. We were interested to discover that students preferred more Teacher Support (Figure 4). Students' comments reflect the independent nature of the course delivery, especially the constructivist model of building one's own knowledge, which is perhaps new and different from other courses that they take:

I don't get the impression that I am on the top of her priority list.

Sometimes I just want to work.

She has no time for small talk. She is so busy with students who need her help.

We have to figure out more for ourselves in this class. I wish she would teach us more.

She is always helping someone and I don't need her help much.

She moves around the room.

Helps us.

Really helpful.

Gives you easier or different examples so you get it.

Conclusion and Significance

The study was comprehensive in that it encompassed a large sample of 1,173 Canadian students who provided both their actual and preferred perceptions of two different school subjects (mathematics and science) in schools which have established a laptop computer programme. There has been little research into the impact that laptop computers have on students' perceptions of their learning environment and their attitudes to science and mathematics. This study found that generally the classroom environment in classes using laptop computers was more favourable for girls than boys, and for science than mathematics.

This study demonstrated that the What is Happening in this Class (WIHIC) questionnaire and attitude scales are reliable and valid for used in grade 7-12 mathematics and science classrooms

where laptop computers are used. Data analyses supported the factorial validity and internal consistency reliability of each scale. Also the actual versions of WIHIC scales were capable of differentiating between the perceptions of students in different classes.

Differences between actual and preferred environments scores were statistically significant for all scales, with students preferring a more favourable classroom environment than the one that they perceived that they were actually getting. This replicates past research (Fisher & Fraser, 1983). This information can provide teachers with a basis for growth and change. The large effect sizes, ranging from one third to almost one standard deviation, suggest that actual-preferred differences are educationally significant.

This study also illuminated factors which affect students' perceptions of their learning environment and their attitudes towards the study of mathematics and science and towards computers in a fully-integrated laptop programme. Relative to mathematics classes, science classes had statistically significant higher scores on actual and preferred Investigation, actual and preferred Computer Usage and Attitudes towards the Subject. For these five scales, the effect size ranged from 0.30 to 0.99 standard deviations. Again these differences can be a basis for growth and change for mathematics and science teachers as they examine the information provided about what psychosocial factors in the learning environment promote positive student attitudes.

We also found statistically significant gender differences. Males scored higher than females on Attitude towards Subject and Attitude towards Computers, but females had higher scores than males on preferred Teacher Support, on actual and preferred Cooperation, and on actual and preferred Equity. The effect sizes for these differences ranged from a third of a standard deviation to almost one standard deviation, indicating important educational differences. These findings can provide teachers with information about how to make laptop classrooms more equitable for boys and girls and about students' learning environment. In turn, this information could help teachers to adopt strategies that might improve the learning environment in laptop computer classrooms.

Finally, considerable past research (Fraser, 1998) was replicated in that relationships were found between students' attitudes and their perceptions of the actual classroom learning environment as assessed by the WIHIC.

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